

The biological characteristics of the Nile tilapia (*Oreochromis niloticus*) in the Weija Reservoir, Ghana

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Abstract. Kpelly DK, Blay Jr.J, Yankson K. 2022. The biological characteristics of the Nile tilapia (*Oreochromis niloticus*) in the Weija Reservoir, Ghana. *Intl J Bonorowo Wetlands* 12: 41-54. Studies on the biological characteristics of the Nile tilapia (*Oreochromis niloticus* L.) were undertaken in a manufactured lake, the Weija Reservoir, in Ghana from September 2007 to August 2008. From commercial landings, a sum of 657 specimens of *O. niloticus* was examined, of which 357 were males and 300 were females (sex ratio of 1: 0.84; $P < 0.05$). GSI was highest in March and May 2008 and low in December 2007 and August 2008, which suggested that *O. niloticus* spawned throughout the year, but major spawning occurred in March. The length at first sexual maturity (L_{50}) was 16.33 cm for males and 13.49 cm for females. Observations on the frequency distribution of ovum size measured between 1.2 to 3.1 mm showed two distinct peaks that were not completely separated, which were probably shedding eggs in batches, indicating protracted spawning in the population. Fecundity ranged from 563 to 1542 ova for fish of total length 15.6-21.5 cm with a mean of 851 ± 13.2 eggs. The relationships between fecundity and body weight (BW) and fecundity (F) and total length (TL) were: $F = 0.519 BW + 785.4$ and $F = 12.36 TL + 628.5$. Furthermore, based on studies on monthly fluctuations in the GSI and the occurrence of the ripe gonad, the major reproductive activity of *O. niloticus* in the reservoir coincided with months with increasing total alkalinity, reduced water temperature, and dissolved oxygen. The regression coefficient of 3.1 for the length-weight relationship (for both females and males) was not significantly different from the expected value of ($P > 0.05$), indicating isometric growth of the population. Therefore, collection of the species as seed for stocking or brood stock or by fish farmers is recommended in March-April. Moreover, appropriate management policies with periodic studies of the fishery and the limnology of the reservoir are essential to sustain fishery production.

Keywords: Body weight, fecundity, *Oreochromis niloticus*, Weija Reservoir

INTRODUCTION

Fish supplies over 50% of the total animal protein consumed in developing countries, a little below this value in developed countries among the first natural resources to be exploited by man (FAO 2000). It is the most important source of animal protein in Ghana, contributing about 60% of the daily animal protein intake (Frimpong et al. 1992). Among various protein sources, fish stands out as the most important concerning food security because its low price is very competitive compared to the price of other high-quality protein sources such as milk, meat, and eggs (FAO 2000). Moreover, it is the only source of high-quality protein whose shelf life can be readily enhanced through low-cost sustainable technologies such as smoking, drying, and salting.

Tilapias are among the most important warm-water fishes used for aquaculture production. The culture of Tilapia is practiced in over 80 countries in the tropical and subtropical regions globally, with a total production of 478,641 metric tonnes and an average compound growth rate of about 12% yearly since 1986 (FAO 1997; Lovshin 1997). Regarding Balarin and Hatton (1979), Tilapia's culture can provide a welcome solution to the insufficient protein supply in numerous developing countries. Furthermore, from simple waste-fed fish to intensively stocked and managed culture systems, Tilapias are widely

known as one of the most important groups of cultured purposes finfish in a wide range of freshwater culture systems (Pullin 1985; Fitzsimmons 2000). Moreover, attempts to grow them in full-strength seawater have also been made in some developed countries. However, the research in full-strength seawater (32 ppt) observed extremely poor hatching success in ova spawned (Watanabe et al. 1992).

Tilapias belong to the family Cichlidae with three well-known genera: *Tilapia*, *Oreochromis*, and *Sarotherodon*. The species are classified mainly according to some extent, their feeding habits, biogeography, morphology, and to differences in their mode of reproduction. (Lowe-McConnel 1958). Members of the genus *Tilapia* (for example, *Tilapia zillii*) are substrate spawners. Both parents aerate the brood, protect, guard, and help move the clutch to different nest sites. The fry at first feeding is 4-6 mm long (TL) and shows feeble swimming ability, resulting in relatively low fry survival (Lowe-McConnel 1958). The genus *Sarotherodon* shows biparental or paternal care. In *S. melanotheron*, for example, both parents stay close to each other, and their eggs and fry are brooded in the oral cavity of the male, with the females sometimes helping when the male fails to pick up all the eggs. The fry is between 7-9 mm (TL) at first feeding, with well-developed fins for swimming, giving them a high fry survival (Lowe-McConnel 1958; Pauly 1976). In the genus *Oreochromis*,

they are regarded as maternal brooders due to the female is solely involved in the brood care by orally incubating the fry until they reach the free-swimming stage (Lowe-McConnel 1958; Pauly 1976). The female was also observed to leave the nest to orally brood her clutch in safety among the submerged rocks and vegetation with an extended caring period during which fry seeks shelter in the buccal cavity of the female. This genus includes *Oreochromis niloticus* (L.), commonly called Nile tilapia.

The *O. niloticus* and its hybrids are the most important cultured fish species, particularly the subspecies *O. niloticus niloticus*, which is becoming an increasingly important food fish globally (Pullin et al. 1991; Garibaldi 1996). The *O. niloticus* is the major species farmed in Ghana and, according to FAO (2005), constitutes over 80 % of aquaculture production in the country. It occurs in several rivers and natural as well as manufactured lakes. The yields are almost fixed at their maximum from many capture fisheries (FAO 1997), while the global human population continues to increase rapidly (FAO 2005), and to meet the increased demand for food fish, aquaculture production should increase by 50 million metric tonnes by 2050 (Tacon 2001).

Many tilapias' biology in natural systems is well documented (Fryer and Iles 1972; Pauly 1976; Siddiqui 1977; Trewevas 1983; Silva 1985; Blay and Asabere-Ameyaw 1993; Njiru et al. 2006; Olurin and Aderibigbe 2006). However, despite the predominance of *O. niloticus* in the Weija Reservoir, the key characteristics of the species' biology in reproduction and its growth have not been fully observed. Therefore, this research seeks to present important scientific data by examining aspects of

the biology of *O. niloticus* in the Weija Reservoir, a manufactured lake, that are relevant to its culture.

MATERIALS AND METHODS

Study area

The Weija Reservoir, also known as Lake Naye Densu, is part of the 116 km long River Densu located about 17 km west of Accra ($5^{\circ} 33'$ and $5^{\circ} 36'$ N; $0^{\circ} 20'$ and $0^{\circ} 23'$ W), which takes its source from the Atewa Atwiredu mountain range in the Eastern Region of Ghana. (Figure 1). It was created to replace an earlier dam that collapsed in 1968. The Weija Dam was constructed in 1978 by Ghana Water Company Limited (GWCL), intending to provide potable water for domestic consumption, while fisheries development and irrigation serve secondary purposes. The reservoir is 2.2 km wide, 14 km long, and has a total surface area of 38 km² with a mean depth of 5 m (Vanden-Bossche and Bernacsek 1990). The catchment area covers 2,460 km², and the reservoir irrigates about 220 ha of land (Gordon 2006). The average water temperature is 27°C, and rainfall in the area is seasonal, with an annual average of 65.5 mm and peaks in June and September, while the dry period is between December and March (Asante et al. 2006). The vegetation is of the coastal savannah type around the lake, mainly characterized by grasses, shrubs, and some trees dominated by *Cassia* sp. The main economic activities in the catchment area are crop farming and fishing. The crops cultivated are cassava, sugar cane, maize, and vegetables.

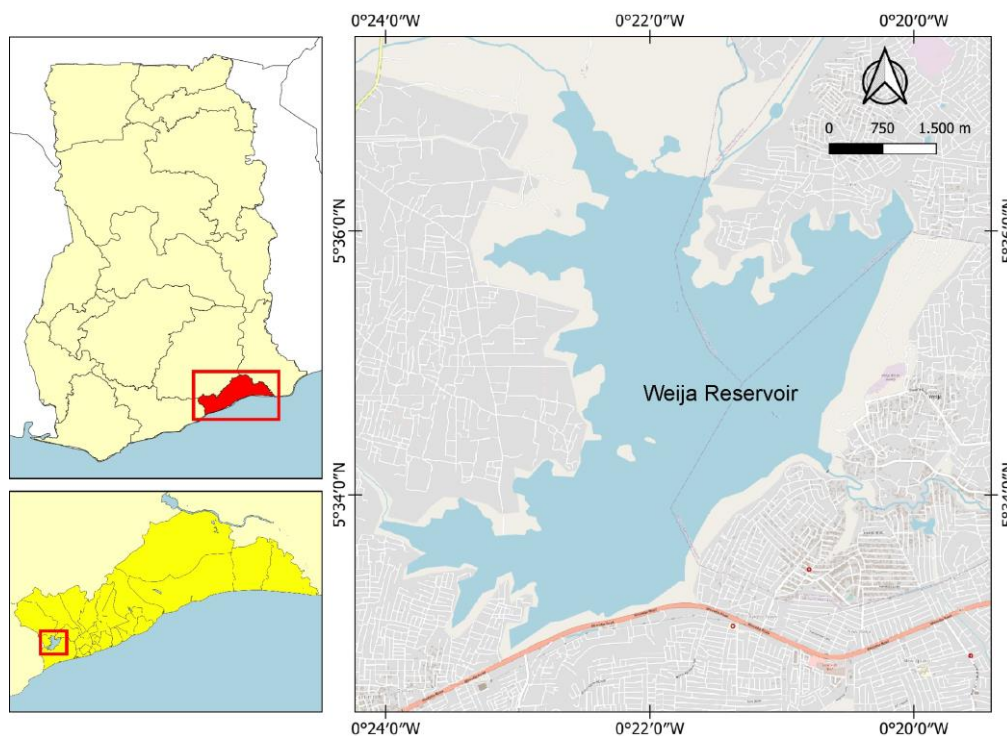


Figure 1. Map of Weija, Ghana area showing the reservoir (Source: Ghana Survey Department 2008)

Fish sampling and data collection

Fish samples were obtained in the middle of each month from September 2007 to August 2008 from commercial landings at the New Galilea landing site of the Weija Reservoir (Figure 1). The fish were caught with cast nets (20.0 mm) and gill nets (large mesh size 50-70 mm, knot to knot; medium mesh size 30-40 mm; small mesh size 10-25, and overall net size about 20 m long). The samples transported to the laboratory for routine studies (at least 40 specimens) were kept on ice in a plastic container.

The total length (TL) and standard length (SL) were taken to the nearest 1.0 mm using a fish measuring board in the laboratory. The total length and the standard length from the tip of the snout to the base of the caudal fin were measured from the tip of the snout to the end of the caudal fin. The fish body weight (BW) was determined to the nearest 0.01g using an electronic top loading balance, and the fish were blotted dry with a towel. Each fish was dissected to determine its sex, and the gonads were removed and weighed using an electronic top-loading balance to the nearest 0.01g.

Determination of length frequency distribution and length-weight relations

The data obtained on the standard length (SL), total length (TL), and body weight (BW), were analyzed to investigate the monthly length-frequency distribution and length-weight relationships to show the recruitment of the fish and their growth pattern.

Determination of condition factor (K)

The measurement data obtained of body weights (BW) and standard lengths (SL) were used to calculate each fish factor (K) condition using the formula:

$$K = \frac{BW}{SL^3} \times 100 \quad (\text{Tesch, 1971})$$

The mean monthly condition factor of female and male fish was plotted to illustrate the fluctuations in the relative fish's 'fatness' or 'well-being' during the study period.

Determination of visceral fat index

After dissection, each fish's visceral fat amount content was observed and estimated using a three-point scale, according to Kwei (1970), and recorded as follows: 1: viscera with very low-fat volume; 2: viscera with moderate fat volume; 3: viscera with high-fat volume.

The data on the fat index of the male and females were analyzed using Minitab (version 15) statistical software, obtaining their mean monthly fat index and standard errors. Then, these were plotted using Microsoft Excel (version Office 2007) to observe the fish 'fatness' fluctuations, indicating their condition.

Determination of the sex ratio

After sexing the fish, the monthly sex ratio of male to female fish was determined using the data obtained. In addition, a Chi-square goodness of fit test was also performed to observe any difference in the sex ratio of 1:1

on the monthly samples from the *O. niloticus* population.

Gonadal staging

Based on their appearance, the gonads of the fish were examined and staged, according to Witte and Van Densen (1995). The three-point scale was used to stage ovaries: Stage 1- Immature: small haline ovaries with very small whitish ova; Stage 2- Developing: ovaries with yellow ova or few yellowish-white; Stage 3- Ripe: gravid ovaries with large yolky ova.

Testes were classified as either ripe or immature due to difficulties describing intermediate developmental stages. Testes of immature fish were thin and very transparent, while ripe testes were swollen with milt and creamy or reddish, which flows out easily when the testes are cut. The monthly fluctuations of the ripe gonads in the fish were obtained from the percentage of ripe males and females in each monthly sample that was determined and then plotted.

Determination of gonado-somatic index (GSI)

The gonado-somatic index (GSI) of females and males was calculated as

$$GSI = \frac{GW}{BW - GW} \times 100 \quad (\text{Htun-Han, 1978})$$

Where, GW is gonad weight (g), and BW is body weight (g).

Next, to obtain the mean monthly GSI of the fish and their standard errors, the data were analyzed using Minitab (version 15) statistical software. In addition, the mean monthly GSI of both male and female fish were plotted to determine the changes in the reproductive activities of the fish.

Determination of fecundity

The fecundity was determined by the whole count method (Bagenal and Braum 1978). First, all ripe ovaries were cut into pieces and preserved for about four weeks in sample bottles containing Gilson's fixative. That was done to ensure the hardening of the eggs and permit infiltration of the ovarian tissues by the fixative. Next, each bottle was periodically agitated vigorously to facilitate the separation of the eggs from ovarian tissues (Bagenal and Braum 1978). Then, the content was poured into a petri dish, and eggs were separated from the ovarian tissue using a dissecting pin and a pair of forceps before counting. Finally, all ripe eggs in an ovary were counted, and using analysis of variance, the relationship between fecundity, standard length (SL), and body weight (BW) were established.

Determination of length at first maturity (L₅₀)

The data on the fish's total length (TL) and gonadal stages were used to determine the length at first maturity (L₅₀). In addition, the percentage of males and females considered mature for the selected class size was used to determine the maturity percentage. Finally, these values were used to plot graphs for males and females using the statistical software Origin Professional (version 6.0) to

estimate the length at which 50% of the population is sexually mature.

Measurement of ovum diameter

A sum of four ripe female ovaries diameters selected at random were used. After determining the fecundity, the ova were measured using a dissecting microscope with a stage micrometer on their longest axis to the nearest 0.1 mm and recorded. Next, in the diameter class at 0.2 mm intervals, the data for each pair of ovaries selected were sorted and grouped. Next, using Microsoft Excel (version Office 2007), the data was used to plot the ovum diameter frequency distribution to predict the fish's spawning frequency.

Hydrographic factors

Data on the monthly mean on some hydrographic factors, namely, dissolved oxygen of the surface water of the reservoir, temperature, and total alkalinity, were obtained from the study period from the Ghana Water Company Limited (GWCL)/AVRL at Weija (see Appendix 6). Next, to show their range and monthly fluctuations during the study period, the data were plotted using Microsoft Excel (version Office 2007) to show any possible relation between them and the growth or reproductive activities of the fish.

RESULTS AND DISCUSSION

Monthly length-frequency distribution

The monthly length-frequency distributions of *O. niloticus* in the Weija Reservoir from September 2007 to August 2008 are presented in Figure 2. Most of the fish sampled ranged from 14 to 20 cm TL. Apart from November 2007, where juveniles were encountered, other monthly samples were skewed towards individuals measuring 12 or 13cm (TL). Males were relatively larger than females, as shown in the modal classes of 16.0 –16.9 cm and 19.0 – 19.9 cm for female and male fish, respectively. The distribution size was bimodal in July 2008, with the modal groups as 14.0-14.9 and 20.0-20.9 cm TL. In September, October, November, and December 2007, they presented unimodal distribution with their modal class within 17.0-17.9, 18.0-18.9, 12.0-12.9, and 13.0-13.9 cm, respectively. Furthermore, in January, February, March, April, May, June, and August also presented unimodal distribution with their modal classes in the 11.0-11.9, 15.0-15.9, 16.0-16.9, 15.0-15.9, 12.0-12.9, 16.0-16.9 and 19.0-19.9 cm respectively. In Juli, bi-modal size distribution was observed with the modal classes in the 14.0-14.9 cm and 20.0- 20.9 cm size groups.

Length-frequency distribution of female and male

Figure 3 shows the length-frequency distribution for females and males. The females and males distributions were unimodal, with the modal classes within the 16.0-16.9 cm and 19.0-19.9 cm groups, respectively. The males were also larger than the females, apart from the fact that more males (N= 357) were encountered. The smallest fish size

obtained was a female in the 7.0-7.9 cm group, and the largest female obtained belonged to the 30.0-30.9 cm group. The smallest male was within the 8.0-8.9 cm group, with the largest in the 33.0-33.9 cm group.

Overall length-frequency distribution

The overall size-frequency distribution of *O. niloticus* in the Weija Reservoir during the study period is shown in Figure 4, with the modal size within 17 cm TL; thus, the distribution is unimodal. A total of 657 specimens with a total length range of 7.0-33.3 cm were sampled.

Length-weight relationship

Figure 5 is shown the scatter plots of the length-weight relation of the population of *O. niloticus* in the Weija Reservoir during the study period and the curve of this relationship. In all the 657 specimens sampled, the total length (TL) ranged between 7.0 and 33.3 cm, and weighed between 17.85 g and 700.00 g. The relationship between the standard length (SL) and body weight (BW) revealed was exponential, with the equation describing this relationship as $BW = 0.0317 SL^{3.0932}$ (Figure 5). In addition, Microsoft Excel (version Office 2007) generated a student t-test which revealed that $b = 3.0932$ was not significantly higher ($P > 0.05$) than the expected 3.0 (see Appendix 2).

Condition factor

Figure 6 shows the condition factor (K) fluctuations of females and males of *O. niloticus*. The mean monthly condition factor ranged from 3.76 ± 0.06 to 4.96 ± 0.125 for the males and from 3.56 ± 0.191 to 4.31 ± 0.131 for the females. During the study period, the condition factor for both sexes seemed to follow a similar trend, except for May 2008, with the males being relatively higher. The fish's best condition was in October 2007, declining in November 2007 and not varying significantly for the rest of the study period in 2008 except in May 2008.

Analysis of visceral fat index

The female and male *O. niloticus* monthly fluctuations in the visceral fat index in the Weija Reservoir are presented in Figure 7. During the study period, the female visceral index ranged between 1.17 ± 0.09 and 1.87 ± 0.15 , that is increased from 1.57 ± 0.16 in September 2007, reaching a peak of 1.87 ± 0.15 in November 2007. The females' fluctuations in the visceral fat index were generally irregular, with the lowest value of 1.17 ± 0.10 observed in April 2008. On the other hand, the visceral fat of males decreased from 1.65 ± 0.11 in September to 1.42 ± 0.10 in December 2007, which reaching a peak of 2.69 ± 0.15 in March 2008, and then dropped sharply till May 2008, where the lowest value was observed at $1.23 \pm$. The visceral fat of males then increased steadily from June, reaching $1.82 \pm$ in August 2008, with two major peaks observed in March and August 2008. Generally, males' monthly visceral fat index was higher than the females except for November 2007 and June 2008.

Sex ratio

Table 1 shows the monthly sex ratio of *O. niloticus*; from a total of 657 Nile tilapia examined, 357 were males, and 300 were females, giving a sex ratio of 1:0.84 overall. Except for January, March, and June 2008, where the females outnumbered the males, the males generally were more in all the monthly samples. However, the sex ratios for the monthly samples of April, July, and August 2008 differed significantly from the expected 1:1 in favor of the males.

Fecundity

The absolute fecundity from the Weija Reservoir of 94 individuals of *O. niloticus* was observed. The fecundity

ranged from 563 ova for fish weighing 108 g and measuring 15.6 cm TL to 1,542 ova for fish weighing 200 g and measuring 21.5 cm TL. The mean fecundity of examined fish was 850.8 ± 13.2 . Figure 8 presents the relationship between fecundity (F) and total length (TL), and the relationship between fecundity and body weight (BW) is presented in Figure 9.

The equations describe the relationships:

$$F = 12.36TL + 628.5 \quad (r = 0.40)$$

$$F = 0.519BW + 785.4 \quad (r = 0.37)$$

The correlation value was weak between fecundity and body weight ($r = 0.38$) and fecundity and total length ($r = 0.4$).

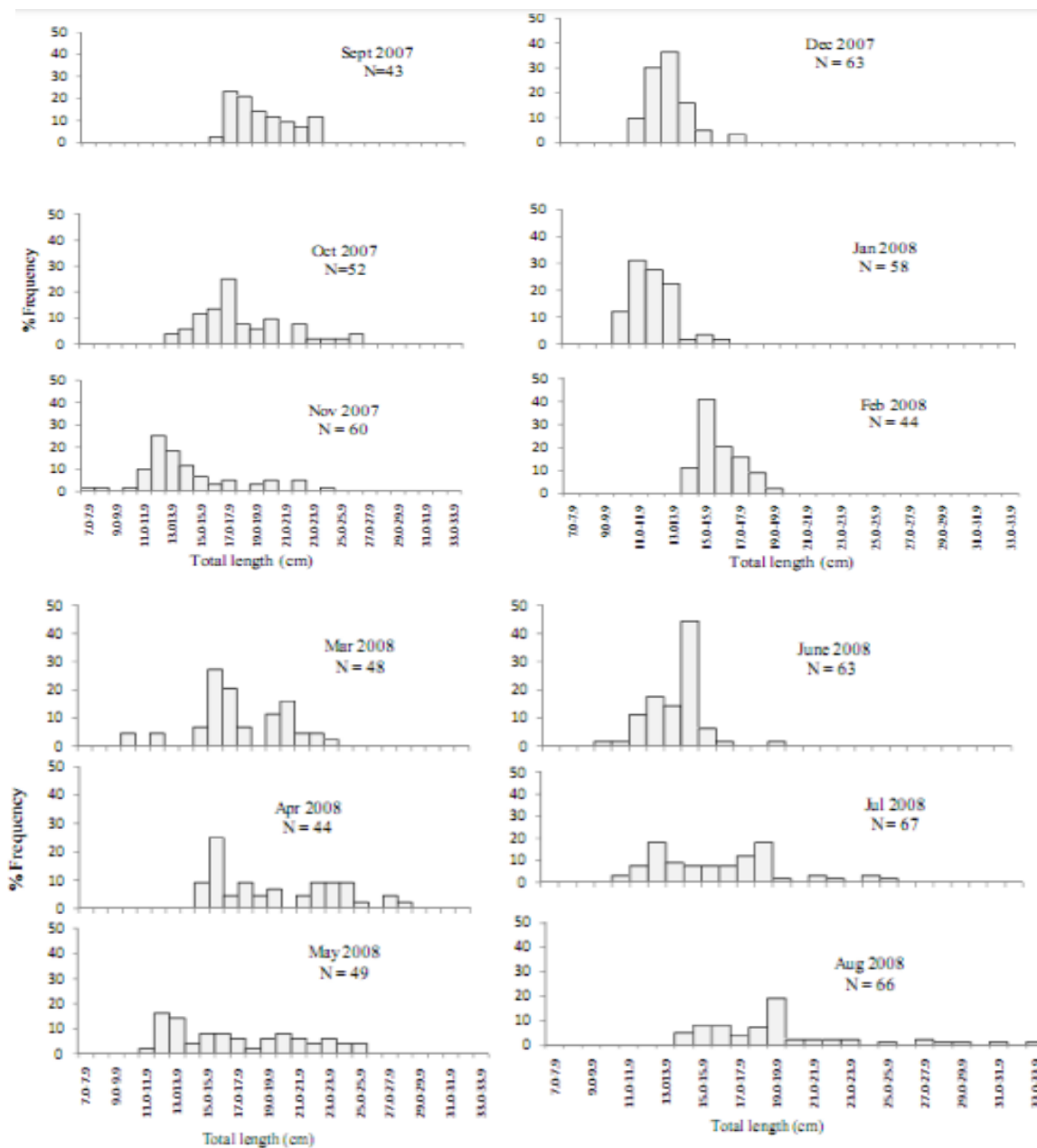


Figure 2. The monthly length-frequency distribution of *O. niloticus* caught in the Weija Reservoir, Ghana

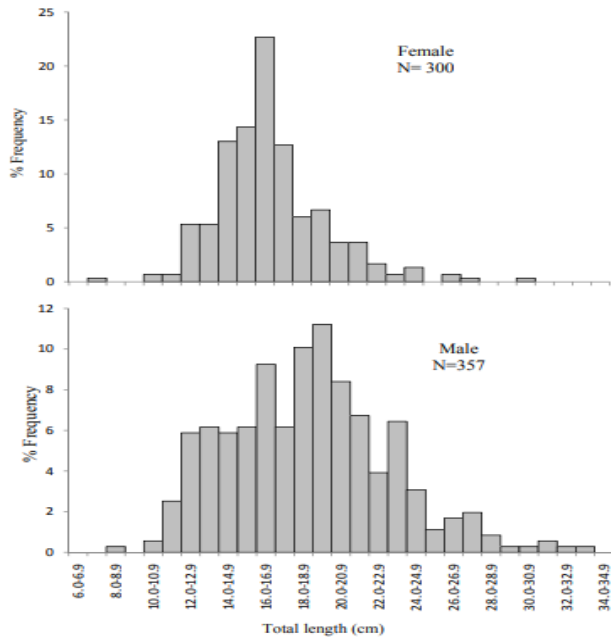


Figure 3. The female and male *O. niloticus* length-frequency distribution caught in the Weija Reservoir, Ghana, from September 2007 to August 2008 (N=total number of fish)

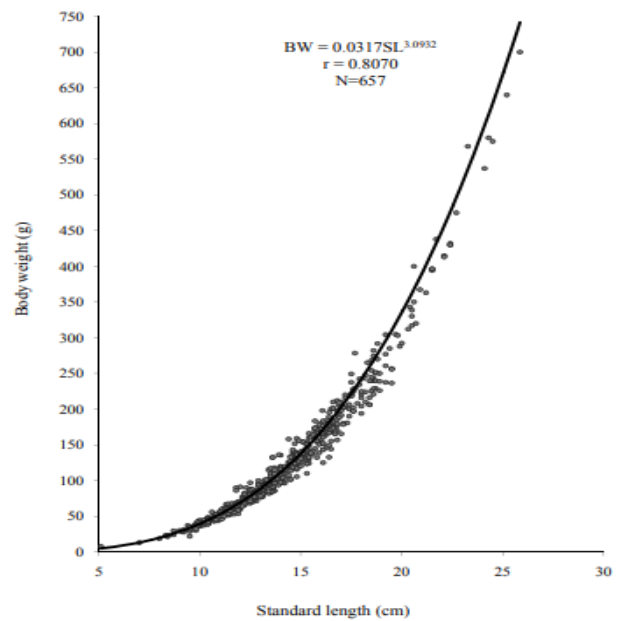


Figure 5. Length-weight regression of the *O. niloticus* population in the Weija Reservoir, Ghana, from September 2007 to August 2008

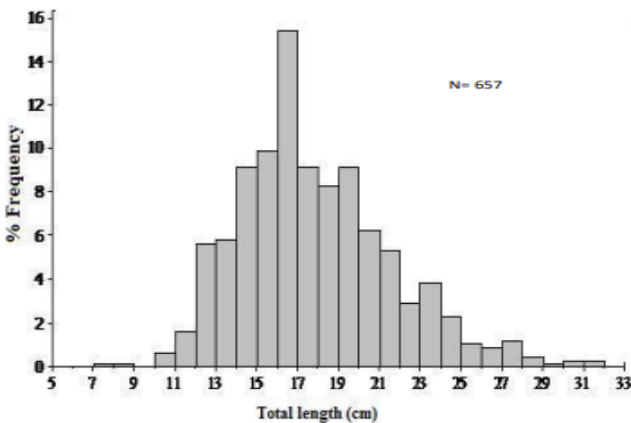


Figure 4. The overall *O. niloticus* length-frequency distribution caught in the Weija Reservoir from September 2007 to August 2008 (N= number of fish)

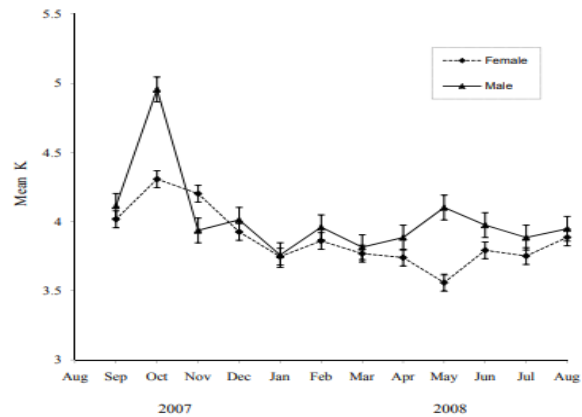


Figure 6. The fluctuations of *O. niloticus* Condition Factor (K) in the Weija Reservoir, Ghana (vertical bars = standard error)

Length at first maturity (L_{50})

Figure 10 is presented the fitted logistic curves for length at first maturity of both male and female *O. niloticus* in the Weija Reservoir. The majority of the fish obtained were sexually mature. The fish attains maturity beyond 10.00 cm TL. Females larger than 13.49 cm TL have a 50% and more chance of being sexually mature. Males with a size greater than 16.33 cm TL also have a more than 50% chance of being sexually mature.

Fish of a total length greater than 18.00 cm are expected to be fully matured. Males mature larger ($L_{50} = 16.33$ cm) than females ($L_{50} = 13.49$ cm).

Fluctuations in ripe gonad representation

Figure 11 is presented the monthly occurrence of ripe gonads in the samples. The percentage of ripe testes ranged between 7% and 100%, and that of the ovaries was between 15% and 53%. The percentage of *O. niloticus* ripe testes peaks occurred in September 2007, February, and July 2008, while ovaries occurred in September 2007 and March 2008. The lowest value for the percentage of ripe ovaries occurred in June 2008, and the testes were recorded in November 2007.

Figure 12 represents the relationship between monthly variation in ripe gonads representation and some hydrographic factors (dissolved oxygen, temperature, and total alkalinity) of the Weija Reservoir. The water's dissolved oxygen concentration decreased from 11.2 mg/L

in September 2007 to 7.8 mg/L in January 2008, then increased to 9.7 mg/L in March, and finally decreased to 6.6 mg/L in June 2008. The oxygen content after that increased steadily to 7.6 mg/L in August. From September to October 2007, the water temperature remained at 27.5°C, then increased to 29°C in November and dropped to 26.7°C in January 2008. In February 2008, a sharp increase in the water temperature was observed, reaching the highest value of 30.5°C, then this value dropped sharply to a minimum of 23°C the following month. The water temperature again increased steadily to 27.8°C in June and then declined slightly to 26.8°C in August.

In October 2007, the minimal total alkalinity value of 98 mg/L was recorded, then increased through November, December 2007, and January 2008, and a maximum of 128 mg/L was reached in February. There was a slight drop in the water's total alkalinity in March and April 2008, followed by a sharp drop to a value of 100 mg/L in May. The value increased sharply through June and July until 115 mg/L was reached in August 2007. The periods of marked changes in the hydrographic factors (dissolved oxygen, temperature, and total alkalinity) in the reservoir arrived to coincide with the month of the highest ripe ovaries for *O. niloticus* (Figure 12). The highest percentage of ripe testes was recorded in February 2008; however, it seemed to be a phase ahead of the months with the marked changes in hydrographic factors.

Fluctuations in the Gonado-Somatic Index (GSI)

The male and female *O. niloticus* monthly variations of the GSI in the Weija Reservoir are presented in Figure 13. The GSI for females was generally higher than that of males due to heavier ovaries than the testes. In females, GSI values dropped from 2.60 in September to 1.73 in December 2007, after which it increased marginally from January to February 2008, then on March 2008 with a sharp increase in GSI to a peak of 3.63, and generally remained low for the rest of the study period except a sharp decrease followed that in April (2.07). On the other hand, the GSI values for males increased from 0.29 in September

to 0.39 in November 2007, followed by a drop to 0.25 in December 2007. Generally, GSI increased from January, reaching a peak of 0.69 in March 2008, followed by another drop to 0.43 in April 2008.

The maximum GSI value for males was 0.78, observed in June 2008. However, the GSI of both males and females declined from October to December 2007. Then the GSI increased from January to March 2008, with the major peaks observed for both sexes. The trend followed a sharp decline the following month, then decreased gradually during the remaining months.

Figure 14 shows the relationship between some hydrographic factors of the Weija Reservoir and monthly variation in the gonado-somatic index (GSI). The periods of marked changes in the hydrographic factors (dissolved oxygen, temperature, and total alkalinity) observed in March 2008 also seem to coincide with the month with the highest GSI values for male and female *O. niloticus* in the reservoir.

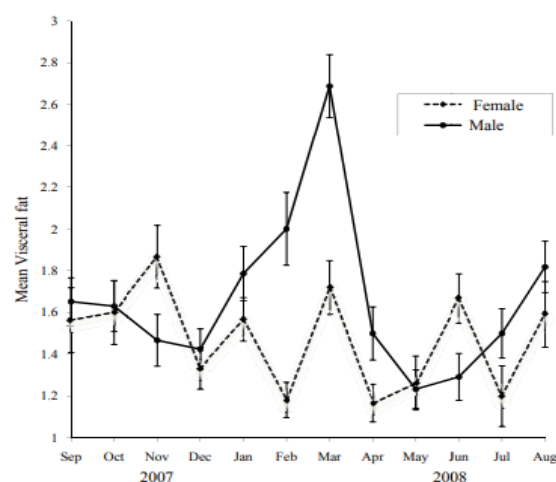


Figure 7. The fluctuations in the visceral fat index of *O. niloticus* in the Weija Reservoir, Ghana (vertical bars = standard error)

Table 1. Sex ratio of *Oreochromis niloticus* in the Weija Reservoir, Ghana

Year	Month	Males	Females	Sex ratio ♂:♀	χ^2	p (0.05)
2007	Sep	25	18	1:0.7	1.14	NS
2007	Oct	27	25	1:0.9	0.077	NS
2007	Nov	30	30	1:1	0.0	NS
2007	Dec	33	30	1:0.9	0.78	NS
2008	Jan	28	30	1:1.07	0.31	NS
2008	Feb	22	22	1:1	0.0	NS
2008	Mar	16	32	1:2	5.33	S
2008	Apr	26	18	1:0.7	1.45	NS
2008	May	30	19	1:0.6	2.47	NS
2008	Jun	24	39	1:1.6	3.57	NS
2008	Jul	52	15	1:0.3	20.43	S
2008	Aug	44	22	1:0.05	7.33	S
	Total	357	300	1:0.84	4.95	S

Note: S = Significant; NS = Not significant. A Chi-square test was examined to indicate that the overall difference from the 1:1 ratio was significant ($P < 0.05$) and in favor of the males ($\chi^2 = 4.95$)

Ovum diameter frequency distribution

Figure 15 illustrates the frequency distributions of the ovum diameter of four ripe ovaries of *O. niloticus*. for fish between 14.4 and 21.0 cm TL, the ovum diameter ranged between 1.2 and 3.1 mm. Two distinct peaks were observed in each ovary studied, not completely separated from each other. The modal sizes were: 1.4 mm and 2.0 mm for fish of a total length of 15.4 cm, 1.6 mm and 2.2 mm for fish of a total length of 16.8 cm, 1.6 mm and 2.2 mm for fish of a total length of 14.6 cm and 1.8 mm and 2.4 mm for fish of total length of 21.0 cm. The batches of ova to be spawned are represented by the peak of the modal sizes

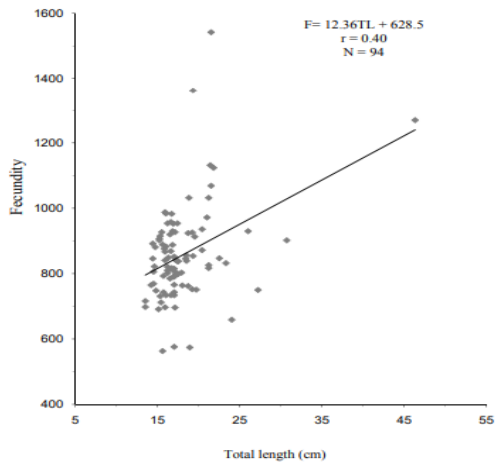


Figure 8. The relationship between fecundity and total length of *O. niloticus* in the Weija Reservoir, Ghana

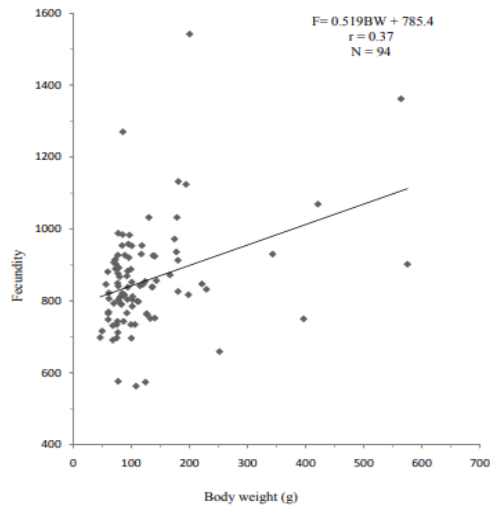


Figure 9. The relationship between fecundity and body weight of *O. niloticus* in the Weija Reservoir, Ghana

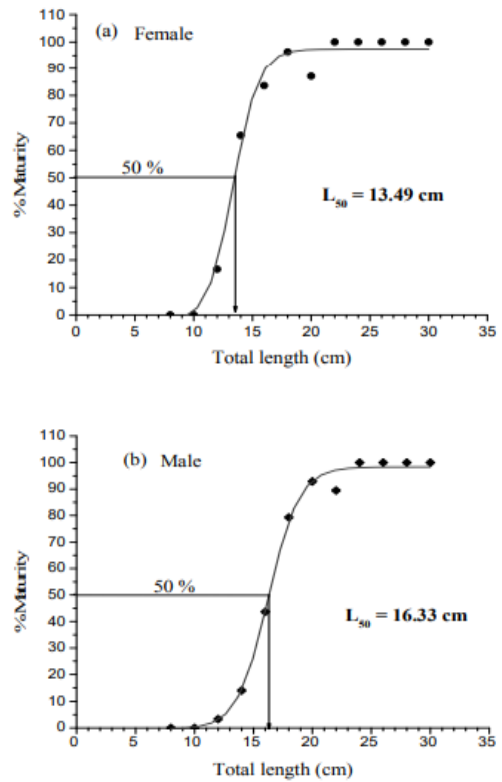


Figure 10. The length at first maturity (L_{50}) of (a) female and (b) male *O. niloticus* in the Weija Reservoir, Ghana ($L_{50} = 13.49$ cm and 16.33 cm for females and males respectively)

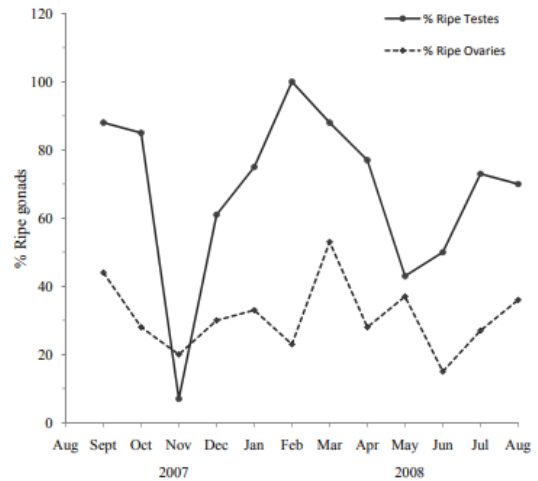


Figure 11. Monthly fluctuations in ripe gonads of *O. niloticus* in the Weija Reservoir, Ghana

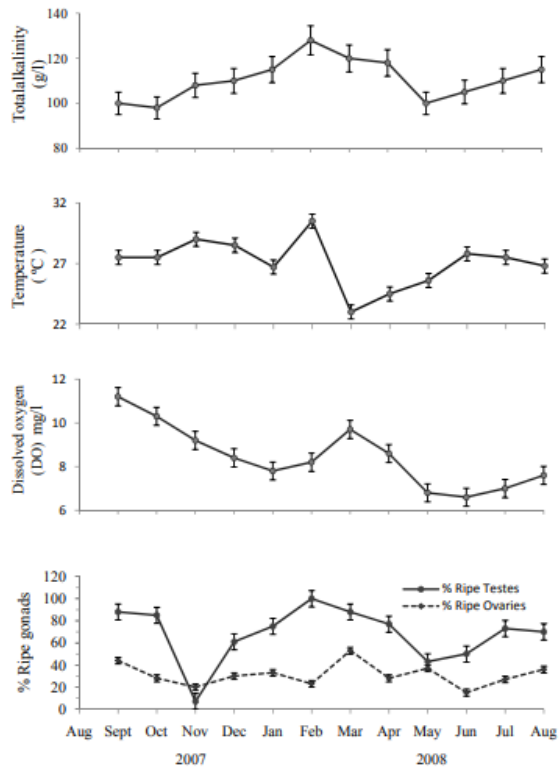


Figure 12. The relation between *O. niloticus* fluctuations in the ripe gonads of and some hydrographic factors (From: GWCL/AVRL-Weija, 2008) of the Weija Reservoir, Ghana (vertical bars = standard error)

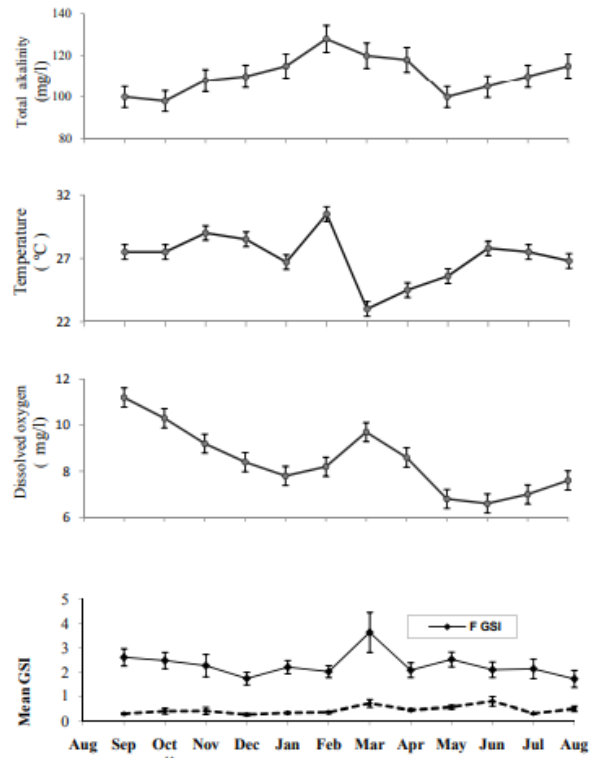


Figure 14. The relation between *O. niloticus* fluctuations in the gonado-somatic index (GSI) of females and males and some hydrographic factors (From GWCL/AVRL-Weija 2008) of the Weija Reservoir, Ghana (vertical bars = standard error)

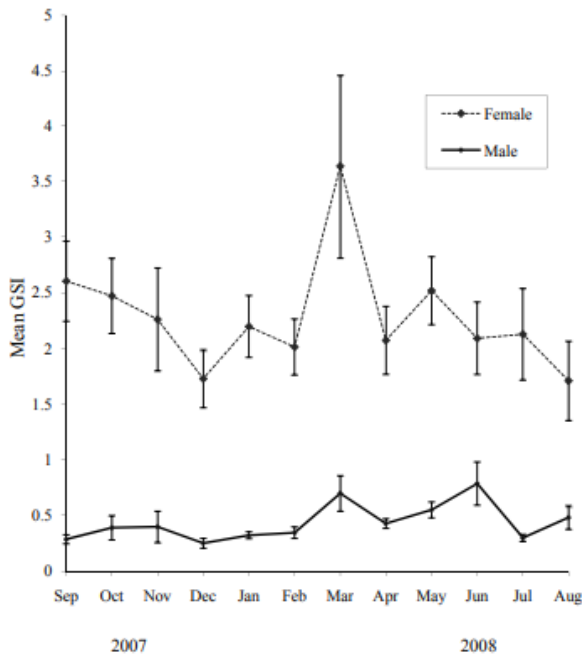


Figure 13. The fluctuations in the Gonado-Somatic Index (GSI) of female and male *O. niloticus* in the Weija Reservoir, Ghana (vertical bars = standard error)

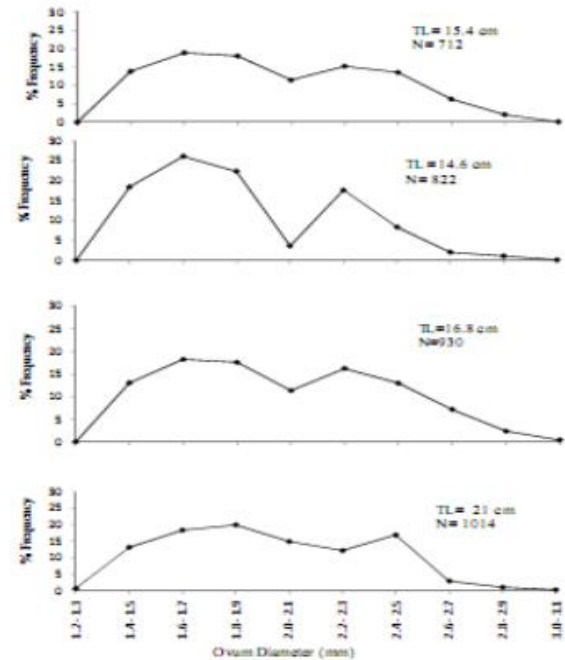


Figure 15. The frequency distribution of *O. niloticus* ovum diameter of four ripe ovaries in the Weija Reservoir, Ghana (N = total number of ova)

Discussion

The range of sizes of *O. niloticus* from the Weija Reservoir was observed at 7.0 to 33.3 cm TL, and this observation could be because of the fishermen's fishing method and the gear they used. Bwanika et al. (2004) reported size ranges of 4.9 to 29.5 cm and 5.0 to 26.0 cm TL of *O. niloticus* in Lake Nyamusingiri and Lake Nyamusingiri, respectively, in Uganda. The present study's wider size range may be because of better water environmental conditions and genetic factors, allowing the Weija population to grow relatively larger than those in the Ugandan lakes.

The *O. niloticus* length-weight relationship was exponential, as described by the relation $BW = 0.0317SL^{3.0932}$ for the length-weight relationship of *O. niloticus* in the Weija Reservoir. That is a common phenomenon in fisheries (Pauly, 1993; King, 1996; Kariman and Hanan, 2008). The relationship on the curvilinear between the length and weight of the species is common among fishes (King 1996). the regression coefficient is 3.0 for an ideal fish that shows isometric growth. (Allen 1978; Bagenal and Tesch 1978; Dalzell 1987), and allometric growth exhibited in populations in which the exponent differs significantly from 3.0. Similarly, Olurin and Aderibigbe (2006) have been reported for pond-reared juvenile *O. niloticus* in Nigeria with a regression coefficient of 3.09, indicating isometric growth in the species. Njiru et al. (2006) observed positive allometric growth in both males and females of the species in Lake Victoria, Kenya. Their regression coefficient reported for the length-weight relationship was 3.22 and 3.32 for females and males, respectively. Barnes (2007) also reported fish ponds in the Sunyani district of Ghana to have negative allometric growth of reared Nile tilapia. The variation in the exponent of length-weight relationships within the same species could be due to different stages in the ontogenetic development, sex differences, and the differences in a geographical location with the associated environmental conditions. (Tudorancea et al. 1988; Kraljevic et al. 1996).

Furthermore, the condition factor studies describe a fish's health and general well-being as related to its environment; it represents how plumpy or healthy the fishes are (Reynold 1968). in the Weija Reservoir, the males of the *O. niloticus* population investigated were generally heavier than the females. However, some researchers have also reported the same similarity (Stone 1980; Behrends 1983; Eknath et al. 1993; Bentsen et al. 1998). Therefore, as suggested by Pagan (1970) and Tave (1980) in the present study, the difference in the growth of the sexes could be attributed to genetic differences between the males and the females observed. Therefore, the observed increase in the condition of Nile tilapia could be attributed to the development of gonad materials just before the breeding seasons. Moreover, the present study also exposes that the periods of better condition in the fish (October 2007 and February 2008) corresponded with months with reduced reproductive activities (see Figure 6). Lowe-McConnell (1958) also observed the similarity trend

in *O. niloticus* in Lake Turkana, as did Moriarty and Moriarty (1973) in Lake George.

The high condition observed on factor value for males in October 2007 might be due to larger matured fish moving into the deeper part of the water after spawning from their spawning arena in the shallow areas, where the fishermen's net easily catches them spawning to avoid competition for food. The changing conditions of fishes could be used to interpret various biological features such as fatness, reproductive activities, food availability, and environmental health (Le Cren 1951; Dadzie et al. 2000).

Studies on visceral fish fat have also been used to explain the well-being of the fish (El-Sayed and Teshima 1991; Hanley 1991; Webster and Lim 2002). Most fish accumulate fat around the visceral organs during reduced reproductive activities and periods of intense feeding (Kwei 1966; Welcomme 1967). The main function of this fat is to store high-energy molecules, which could be utilized during periods of less-feeding activities as they channel their energy into parental care activities and spawning. Fat is digested and serves as a much better source of energy for protein sparing and metabolized with greater relative ease than carbohydrates (Welcomme 1967; El-Sayed 2006). During long periods, fat also provides energy for immediate physiological needs with higher energetic demands. In *O. niloticus*, the excess lipid is deposited mainly as visceral fat during months when there is a high food intake (Welcomme 1967; El-Sayed 2006; Njiru et al. 2006). The species can utilize lipid reserves for energy needs, especially in the females who fast when orally brooding their eggs and young ones (Love 1957). That is evident in the graph of the female fat index (see Figure 7), having several peaks in November 2007, January, March, June, and August 2008, while males have three peaks in September 2007, March, and August 2008. In March 2008, the highest value of 2.69 for males observed may be due to increased feeding. In April 2008, the sharp drop in visceral fat could be attributed to the protracted reproductive activities during the major breeding season in March 2008. Males were observed to have more visceral fat than females since they diverted less energy into reproductive activities (Welcomme 1967; El-Sayed 2006; Njiru et al. 2006). That is in agreement with the present study (see Figure 7), which probably could be a linkage between fat accumulation and spawning. That could be seen in the monthly fluctuation in the visceral fat index and GSI of the females, with peaks of these graphs coinciding in September 2007, January, and March 2008. Reproductive activities probably cause the fluctuation as the fish accumulate fat and become 'lean' after spawning because the females eat very little or no food when they are mouth-brooding their eggs and young and therefore utilize their fat reserves. During these periods, the increase in visceral fat after spawning indicates intense feeding.

The observed overall sex ratio in favor of males of 1:0.84 for the *O. niloticus* population caught in the Weija Reservoir during the study period was significantly different from the expected 1:1 (see Table 1), which indicates that males than females were relatively higher in number. Njiru et al. (2006) presented a similar observation

for the species in Lake Victoria. However, other researchers (Gómez-Márquez et al. 2003; Peña-Mendoza et al. 2005) revealed contradictory observations where females were more in the populations. Fishery workers such as Barioller et al. (1995) associated the occurrence of unbalanced sex ratios with environmental influences such as temperature. The sex ratio variation may be because of the maternal brooding characteristic of the species. That is because once the fertilization of the eggs is completed, males, possibly due to differential sexual migration, leave the spawning areas for the feeding grounds located in the shallow part of the lake, where they are captured. At the same time, females go into submerged vegetation and rocky areas to carry out the oral brooding and protection of offspring and to avoid predators (including fishermen) (Peña-Mendoza et al. 2005; Offem et al. 2007). The movement of spawning *O. niloticus* from foraging to breeding grounds was also reported by Lowe-McConnel (1958) and Rinne and Wanjala (1982). During this time and fishing operations, differential migration of sexes could occur, resulting in more males than females being caught. Balirwa (1998) also observed that different habitats might favor one sex over the other.

In the present study, the cause of the skewed sex ratio in favor of the males might be genetic factors because the species shows differential growth between the sexes. That is supported by the observation of Fryer and Iles (1972) that, in African lakes, it is common for males to dominate because they generally exhibit faster growth than females causing the selection of males against the smaller females, which means that they obtain the size at which they are caught more quickly. In the present study, males grow to a relatively larger size as represented by the length at first maturity and length-frequency distribution of female and male *O. niloticus* (L_{50} = 13.49 cm for females and 16.33 cm for males, respectively, and modal class length TL= 16.0-16.9 cm for females and 19.0-19.9 cm for males, respectively). Furthermore, to some extent, the influence of environmental factors cannot be completely set aside. In the major breeding season on March 2008 observed that females dominated in the monthly sample, which could be because of bias method of fishing employed by the fishermen as they made their catches or set their nets near the breeding grounds in the submerged vegetation and rocky areas targeting the females carrying out oral brooding of their fertilized eggs or fry, that is less actively.

Studies on the fish's total number of ripe ova in the ovary (fecundity) are essential to estimate the reproductive potential of the species in the wild. In the present study, the fecundity of *O. niloticus* ranged between 563 to 1,542 ova for fish with a body weight of 108 g to 200 g and a total length of 15.6 cm to 21.5 cm. This fecundity is low compared to that reported elsewhere. Lowe-McConnel (1955) reported on the fecundity of the species, ranging from 340 to 3,706 eggs in various East African river waters. The fecundity in the range of 864 to 6,316, with an average of 2,141 eggs in the species in the Nyanza gulf of Lake Victoria, Kenya, was also reported by Lung'aya (1992) (see Appendix 5). The dissimilar reports made by some researchers that there is a strong correlation between

fecundity and body weight and fecundity and the total length (Lowe-McConnel 1955; Lung'ayi, 1994; Njiru et al. 2006; Kariman and Hanan 2008), the present study showed weak correlations between fecundity and body weight ($r = 0.38$), and fecundity and length ($r = 0.40$). That could be because the size range observed in the present study is smaller than those reported by other researchers (see Appendix 5). Njiru et al. (2006) observed a decreasing trend in the fecundity of Lake Victoria of *O. niloticus* due to overfishing. The higher fecundity could probably be attained if the population in the Weija Reservoir could grow larger by reducing the fishing pressure on the species.

The length at first maturity (L_{50}) of the fish population is a function of their size (Siddiqui et al. 1997; Mehanna 2007). That may be influenced by environmental factors such as abundance and seasonal food availability, predation, temperature (especially in temperate regions), photoperiods, and the locality. Siddiqui et al. (1997) stated that fish size is influenced by the feeding level, which affects their growth. Moreover, at first maturity (L_{50}), the length is also an essential management parameter that can be used to monitor whether enough juveniles in an exploited population mature and spawn (Mehanna 2007). In this study, the estimated L_{50} for female and male *O. niloticus* was 13.49 cm and 16.33, respectively. The male growth superiority might be because of genetic factors. Fryer and Iles (1972) stated that genetic factors give males a competitive advantage enabling them to have higher survival rates and larger sizes at sexual maturity. The L_{50} values for Coatetelco Lake in Mexico population seemed to be relatively lower than those of the Weija, where the length at maturity was 11.7 cm for females and 12.0 cm for males, respectively (Gómez-Márquez et al. 2003) and Bontanga reservoir (near Tamale in Ghana's Northern region) with an L_{50} value of 9.1 cm for both females and males (Kwarfo-Apegyah 2010). That is because environmental factors such as the Weija and hydrographic factors of the species in the Weija Reservoir are better than those of the Bontanga reservoir and Coatetelco Lake, where the species are stressed. Payne and Collinson (1983), however, studied the *O. niloticus* population in Lake Manzalah, Egypt, and examined L_{50} values of 16.3 cm for females and 17.4 cm for males, respectively, with the higher L_{50} values than those of the present study. According to Ofori-Danson (1999), the population of species in the Yeji area (Stratum VII) of the Volta Lake, Ghana, examined an L_{50} value of 19.73 cm SL. Ochumba and Manyala (1992) observed the *O. niloticus* population in the Sondumiru River, Kenya, even had higher L_{50} values of 31.5 and 27.5 cm for females and males. According to Balirwa (1998), Lake Kyoga also had L_{50} values of 26.0 cm and 23.0 cm for females and males, respectively, which follows with Eknath et al. (1993) they reported on wild strains of *O. niloticus* from Egypt and East Africa grew better than those from West Africa (Senegal and Ghana). On Lake Manzalah and Lake Coatetelco, the females *O. niloticus* in Lake Victoria appear to become sexually mature at a relatively larger size than the males, contrary to what has been observed in the Weija reservoir (Table 2).

Table 2. The maturity length of some populations of *O. niloticus*

Waterbody	Location	L ₅₀ of females (cm)	L ₅₀ of males (cm)	Source
Weija Reservoir	Ghana	13.49	16.33	Present study
Volta Lake at Stratum VII (the Yeji sector)	Ghana		19.73	Ofori-Danson (1999)
Bontanga reservoir (near Tamale)	Ghana		9.1	Kwarfo- Apegyah (2010)
Lake Coatetelco	Mexico	11.7	12.0	Gómez- Márquez <i>et al.</i> (2003)
Lake Manzalah	Egypt	16.3	17.4	Payne and Collinson (1983)
Lake Kyoga	Uganda	26.0	23.0	Balirwa (1998)
River Sondumiru	Kenya	27.5	31.5	Ochumba and Manyala (1992)

This observation can explain no specific reason, and the major contributing factors are probably genetic causes and better environmental conditions. The relatively small maturation sizes of *O. niloticus* in Bontanga reservoir and Coatetelco Lake, than those in Weija, Lake Kyoga, Sondumiru River, and Manzalah, may be indicating a relatively higher level of stunting of the population in Bontanga reservoir and Lake Coatetelco. The phenomenon of 'dwarfing' or 'stunting' in the tilapia population is well known and is one of the major problems in tilapia culture (Fryer and Iles 1969; Lorenzen 2000). Smaller size at maturity may serve as a strategy to maximize reproduction in a topographically restricted habitat, a response to intensive fishing, a response to a high level of competition, or unfavorable environmental conditions such as pollution. This observation follows the findings from Lowe-McConnell (1982) in several East African river waters. She suggested that *O. niloticus* will breed when younger and smaller in small water bodies such as crater lagoons, ponds, and lakes with stressful conditions and delayed maturation when inhabiting large lakes.

Analysis of fluctuations in percentage mature gonads revealed that peaks of percentage mature testes (see Figure 11) appeared to be a phase ahead of that of GSI. In contrast, that of mature ova coincided with GSI. Following the observations by El-Sayed (2006), Welcomme (1985), and Trewevas (1983), this is a strategy in Tilapia of the genera *Oreochromis* to get the males to increase the success of fertilization and get ready for spawning.

GSI is the percentage ratio of the gonad and body weight, and fish with ripe ovaries have higher GSI values. Therefore, the spawning activities of the fish are indicated by the fluctuation of GSI values; during major spawning periods, the value is high, and after spawning, the low values occur. Moreover, because the gonads of the females are generally heavier than the males, the GSI value for the females is higher than that of the males. In the present study, an indication of breeding throughout the years shown by the female *O. niloticus* population exhibited peaks in September 2007 and January, May, and July 2008. While for the females, the major reproductive activities of the males occurred from March to April 2008.

From the hydrographic factors of the water data obtained from GWCL/AVRL at Weija, based on analysis of GSI and occurrence in ripe gonads, it appeared the major spawning period of the *O. niloticus* population coincided with months with lower water temperature (below 24°C),

dissolved oxygen and increasing concentrations of total alkalinity, which possibly corresponds to the major rainy period (see Figs. 12 & 14). This finding agrees that most wild cichlids respond to changes in these hydrographic factors, which serve as indicators that trigger their reproductive activities (Welcomme 1985; El-Sayed 2006). From this study, the *O. niloticus* population in the Weija Reservoir appears to synchronize their major breeding season with periods of favorable environmental conditions for rearing their young juveniles.

The fish species' frequency distribution of ovum diameter can be used to predict the spawning frequency of the fish. The female ovaries contain oocytes of different developmental stages in multiple-spawning fish species. While fish's oocyte distribution with short and definite spawning periods exhibits distinct ovum sizes, those of intermittent spawners do not show any distinct modes (Hickling and Rutenberg 1936). In the current study, the distribution shows two peaks that are not completely separated (Figure 14), indicating that *O. niloticus* in the Weija Reservoir might exhibit protracted spawning, which was possibly shedding the eggs in batches. Moreover, if suitable ambient environmental conditions are attained, the *O. niloticus* can spawn several times a year (Welcomme 1985; El-Sayed 2006). Blay (1981) examined *Sarotherodon galilaeus*, a species-related tilapia, in restricted spawning activity in a small concrete pond. Therefore, the ability to spawn more than once may be a strategy to reduce the risk of wiping out a reproductive run in a season. Welcomme (1967) also reported the range of ova diameters within the range of 1.2 mm to 3.1 mm. Residual eggs that progress into atresia in post-spawned ovaries of the species have been reported (Babiker and Ibrahim 1979; El-Sayed 2006). After spawning, the tilapia ovaries regenerate immediately and rapidly and are recruited in as little as one week (Coward and Bromage, 2000).

In conclusion, the length-weight relationship for *O. niloticus* in the Weija Reservoir is described by the relation $BW = 0.0317 SL^{3.0932}$ which shows that the Nile tilapia population in the Weija Reservoir is growing isometrically ($r = 3.09$). Examinations on the condition factor show that, generally, the males are plumper than the females. The fish obtain their best condition in the months with reduced reproductive activities in February and October.

The Chi-square test result revealed that males of the Nile tilapia population in the Weija Reservoir significantly outnumber the females with a sex ratio of 1: 0.84 ($P <$

0.05). The GSI result and gonadal stages show that the species spawned around the year, and March was the major breeding period. In addition, the frequency distribution of ovum diameter exhibits protracted spawning shedding eggs in batches showing on the females *O. niloticus*. There is also a link between fat accumulation and spawning in females. The fish build up fat reserves before spawning and become lean. Moreover, because males divert less energy into reproductive activities, they have more visceral fat than females. The fish's major breeding period also coincided with total alkalinity concentrations of the reservoir, water temperature slightly below 24°C, and increased dissolved oxygen.

The fish attains maturity beyond 10.00 cm TL. Fish of a total length greater than 18.00 cm are expected to be fully matured. Females mature at a shorter size ($L_{50} = 13.49$ cm) than males ($L_{50} = 16.33$ cm). In the Weija Reservoir, the fecundity of *O. niloticus* ranged between 563 to 1,542 eggs, corresponding to the fish's total length of 15.6-21.5 cm and weight of 108-200 g. There is a weak correlation between fecundity and body weight ($r = 0.38$) and fecundity and total length ($r = 0.40$).

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